CHLORINATION PRIOR TO FILTRATION[1]

By Norman J. Howard[2]

In Toronto, filtration of City water is effected by means of slow sand and drifting sand systems. The plant is detached from the mainland and situated on an Island, a distance of two miles from the city. The water after filtration flows by gravity to a point one mile north of the works, and then drops down a vertical steel shaft 90 feet deep into a tunnel, and flows by gravity under Toronto Bay to the City where it is chlorinated. The unusual location of the plant and the possibility of leakage between the works and the City, are the chief reasons put forward for not chlorinating the water immediately after filtration.

With the idea of facilitating the operating conditions at the plant, increasing the output, and effecting considerable economy on maintenance and operating costs, the system of chlorination prior to filtration was successfully carried out during the past year. For reasons previously mentioned, no attempt was made to sterilize the water, this being left for final treatment on the City side. Chlorine at the plant was simply applied as an economical and effective substitute for alum, and, as results have shown, has proved entirely successful.

The application of chlorine prior to filtration is a rather radical departure from generally accepted practice in water purification. At the present time considerations based upon theoretical and practical observation, would indicate that chlorine should be applied to water immediately after filtration in order to secure the greatest efficiency. The conservative attitude of the engineering profession, so pronounced a few years ago, was possibly a hindrance to progress in water purification. New departures involving radical changes in established practice, often receive scant consideration and little encouragement. Of recent years the extraordinary advances

[1] Presented before the Chemical and Bacteriological Section at the Philadelphia Convention, May 18, 1922.

[2] Bacteriologist in Charge, Filtration Laboratories, Toronto, Canada.

made in the science of water purification, have proved the value of laboratory control and research. In many instances such work has resulted in the establishment of new theories, which, having been worked out on a practical scale, have resulted in considerable modification of views previously held. As an example of this may be mentioned the sterilization of water supplies, the excess lime method for softening and sterilizing water, the hydrogen-ion theory which is claimed to be the controlling factor in many filtration problems and, more recently, the excess chlorine treatment for the removal of taste and odors.

The drifting sand system of purification as adopted by the City of Toronto must be regarded as a combination of slow sand and mechanical filtration processes, and represents the latest departure from standard systems of water filtration. The plant was designed to operate with applied alum at the rate of 1 grain per gallon, but pollution of the raw water increased at such an abnormal rate, that it was found necessary to apply as much as 2.5 grains per gallon in order to secure a satisfactory effluent. The cost of treating from 35,000,000 to 50,000,000 gallons daily involved an enormous expense, and the high dosage of alum had a tendency to lower the output of the plant. The raw water while being highly polluted at times, does not contain turbidity excepting during storm periods and consequently the application of chlorine either before or after filtration presented no difficulties.

The practice of applying chlorine both before and after filtration is not an appealing one, but the abnormal conditions prevailing in Toronto during the warm weather, when the pumpage rate exceeded 100,000,000 Imperial gallons, have more than justified the action of the City. In connection with these conditions it should be stated that the normal filtering capacity of the plants is approximately 88,000,000 gallons, and, by substituting chlorine for alum, the rate of filtration through the drifting sand plant was increased from 150,000,000 to 175,000,000 Imperial gallons per acre per day, thus yielding additional water at the rate of 10,000,000 gallons per day. The rate of filtration was of course increased only during peak load periods. During the summer months it has been found that a small dose of chlorine was more effective in reducing the bacterial content, than was alumina sulphate, when applied in doses up to 1.5 grains per gallon. In the winter months purification effected by the use of alum compared more favourably with chlorine.

The only objection raised to pre-chlorination was the possibility of taste production, always bearing in mind that the water had to be finally treated on the City side. It must be admitted, particularly in view of the history of taste conditions in Toronto, that the objection was justified. In the first instance it was our intention to apply chlorine and alum alternately, according to prevailing physical and meteorological conditions. This policy was carried out until the months of July and August when chlorine was applied continuously. The water of Lake Ontario is susceptible to taste after chlorination when easterly winds prevail, and at such times, excepting in the months previously mentioned, alum was substituted for chlorine. In the spring and fall the iodoform taste periodically developed, but there is nothing to indicate that pre-chlorination had anything to do with it, as on all occasions, the use of chlorine had been discontinued several hours prior to the taste developing. It is an interesting fact, however, that during the past year taste occurred more frequently than in the previous year when alum was being applied continuously, but the fact remains that no taste occurred in July and August when chlorine only was being applied. Generally speaking during the months of August and September taste often occurs. If it is borne in mind that easterly winds prevailed on 44 per cent of days during August, when chlorine was applied, no taste occurring, and that the dose of chlorine was well above the average in September, due to warm water, the relationship of pre-and final chlorination to taste producing conditions is not apparent. Nevertheless great care was taken to avoid taste, and any unusual conditions at the plant resulted in the temporary discontinuance of chlorine.

PURIFICATION

For the purpose of comparison the average of all results and the purification effected by alum and chlorine separately are given below.

Allowing for the fact that the quality of the raw water was worse when alum was being used, it will be seen throughout the entire tables that the figures after chlorination and filtration, were proportionately better than when alum was being applied. In the month of September, on two occasions when the water was heavily polluted, the dosage of chlorine applied was 0.2 p.p.m. Results showed this amount to have been insufficient, with the quality of the water experienced at the time. If these two results were excluded

from the chlorine figures, the average count on agar would have been reduced from 18.12 to 8.1 per cubic centimeter, rebipelagar figures from 0.44 to 0.25 and the B. coli index from 0.71 to 0.21 per cubic centimeter. The reason for keeping the dosage low was to avoid the possibility of taste, but it is probable that a dose of 0.225

TABLE 1

Bacteria growing on agar at 37°–39°C., twenty-four hours incubation, showing the yearly average number per cubic centimeter, in raw and filtered water and the total percentage reduction in the filtered water for the year

YEARLY AVERAGE		PERCENTAGE REDUCTION
Raw water	Filtered water	
All results included		
566.37	26.29	95.2
When alum alone was being applied		
707.16	44.94	93.6
When chlorine but not alum was being applied		
504.99	18.12	96.3

TABLE 2

Excremental bacteria growing on bile-salt agar (Rebipelagar) at 37–39°C., twenty-four hours incubation, showing the yearly average number per cubic centimeter, in raw and filtered water and the total percentage in the filtered water for the year

YEARLY AVERAGE		PERCENTAGE REDUCTION
Raw water	Filtered water	
All results included		
21.70	1.28	93.8
When alum alone was being applied		
36.03	3.21	91.1
When chlorine but not alum was being applied		
15.45	0.44	96.9

TABLE 3

Indicated number of B. coli per 1 cc. in raw and filtered water and the total percentage reduction in the filtered water for the year

YEARLY AVERAGE		PERCENTAGE REDUCTION
Raw water	Filtered water	
All results included		
752.39	1.68	99.8
When alum alone was being applied		
1168.85	3.89	99.6
When chlorine but not alum was being applied		
570.80	0.71	99.9

TABLE 4

	1920		1921
Alum used, 1219.26 tons....	$60,963.00	Alum used, 363.1 tons....	$18,155.00
Chlorine.....		Chlorine 9.373 tons.....	2,343.37
Additional labor.....		Additional labor.....	5,975.32
Total.....	$60,963.00	Total.....	$26,473.69

Note. Alumina sulphate cost $50 per ton delivered to the plant in 1920–1921. Chlorine in 1921 cost $250 per ton. Additional labor included three men working whole time and one relief man two days weekly.

Total expended in chemicals 1920.....	$60,963.00
Total expended in chemicals 1921.....	26,473.69
Net saving.....	$34,489.31

The average dose of applied alum in 1920 was 1.219 grains per Imperial gallon, while in 1921 it was 1.30 grains. During 1921 the average amount of water filtered through the drifting sand plant was slightly lower than in 1920. This latter difference was balanced by the increased dosage of alum during the past year.

By utilizing the services of the chlorine operators on the plant during such times as the chlorine was not being applied, and by saving in pumpage and backwash water, etc., the superintendant of the plant has estimated a further saving of $5000 during the year 1921, making a total saving of $39,489.31.

could have been safely maintained as at this particular time no taste developed.

In connection with the purification figures two important conditions are involved, firstly that alum was applied at the approximate rate of one grain per gallon excepting during storm and turbid water conditions, clarification of the water being regarded as the first consideration, and secondly no attempt was made to sterilize the water, sufficient chlorine only being added to greatly improve the quality of the effluent. The reason for this latter condition, as has already been stated, was that chlorine was finally applied on the City side.

ECONOMY EFFECTED

The basis for comparison of operating costs of applied chemicals is taken between the years 1920 and 1921. In the former year alum was applied throughout, while in 1921 chlorine and alum were applied alternately.

The question of taste has already been discussed, but it should be mentioned that, when chlorine was applied in amounts varying between 0.150 and 0.3 p.p.m., excess chlorine was entirely absorbed in the drifting sand filters, that is to say tests with starch and iodide indicated its absence. In connection with excess chlorine treatment for eliminating taste, and where pre-chlorination is practicable, the removal of excess chlorine by filtration is worthy of consideration.

From the forgoing facts and figures presented it will be seen that where conditions are suitable chlorination prior to mechanical filtration is a sound and economical method of operation, the advantages claimed being:

1. Purer water obtained.
2. Great economy effected.
3. Operation of plant generally facilitated.
4. Increased rate of filtration possible.
5. Probable removal of chlorine taste.